RESEARCH MEMORANDUM

EXPERIMENTAL ANALYSIS OF MULTICELL WINGS

BY MEANS OF PLASTIC MODELS

By George W. Zender

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON

June 21, 1955

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

EXPERIMENTAL ANALYSIS OF MULTICELL WINGS BY MEANS OF PLASTIC MODELS

By George W. Zender

SUMMARY

The stresses and deflections of a plastic model of a delta multicell wing are presented and compared with theoretical results obtained by the use of the Cal-Tech analog computer. The comparison indicates that valuable information may be obtained for experimental structural analyses from tests of plastic models.

INTRODUCTION

The problems associated with low aspect ratio and high sweep have introduced difficulties which require extensive theoretical analyses and the use of intricate automatic computing machines in the structural analysis of aircraft wings. Such complications introduce considerable theoretical uncertainty and increase the demands for experimental evaluation of the structure. A method of experimental analysis which has been useful in the past involves the testing of scaled models made of plastic. Such a method has been used by Redshaw and Palmer (ref. 1) to obtain results directly applicable to a full-scale aircraft, whereas other investigators have obtained information useful in the analysis of various components of the structure. Nevertheless, the plastic-model approach is often rejected because of the peculiar properties of the plastic material. The National Advisory Committee for Aeronautics has made some tests using plastic models, and it is the purpose of this paper to show the methods which were employed to account for the peculiarities of the material and to present some of the results which have been obtained.

DISCUSSION OF TECHNIQUES

Considerable information on the properties of thermoplastic materials has been published by manufacturers. In general, such data indicate that for experimental purposes the temperature should be relatively low and closely controlled, and the humidity should be maintained reasonably

constant. In addition, the material experiences creep when subjected to stress and the severity of the creep is dependent upon the stress level.

An example of the type of results which are obtained from a structure made of one of the thermoplastic materials is shown in figure 1. The model in this case is a cantilever box beam constructed of $\frac{1}{10}$-inch Plexiglas I-A sheet, has a 2-inch width and depth, is 20 inches long, and has ribs located every 2 inches along the length. The beam was tested in bending in an air-conditioned room at a temperature of 68° F. The strain near the root was obtained on the tensile side of the beam, and a time history of the strain at three stress levels is shown. The circles show the strains for the lowest stress level when the stress at the gage location was 235 psi. After 13 minutes the load was removed, and the gradual tendency of the beam to relieve itself of strain is shown. The cycle was repeated for stress levels of 705 psi and 940 psi, and it is noted that more time is required for the beam to relieve itself of strain as the stress level is increased.

For experimental work it would be desirable to avoid stresses of the magnitudes shown by the upper curve in figure 1 since the strain does not reach a constant level. Tests are sometimes performed at such levels by waiting several minutes after loading before taking measurements in order to avoid the region of the primary effects of creep, and then unloading to permit the structure to relieve itself of strain before proceeding to the next loading. In most cases, however, it is possible to limit the maximum stresses to lower stress levels than those shown by the upper curves of figure 1 and to perform the test in the manner shown in figure 2. In this test the beam was loaded at small stress increments of 162 psi without unloading the beam between successive loadings. It is noted that essentially constant strains were obtained except for the 648 and 810 psi stress levels. Therefore, if it were possible to limit the maximum stresses to about 500 psi, it would appear permissible to perform the tests without unloading between successive loadings. The modulus of elasticity necessary for converting strains to stresses may be obtained from tests of an elementary beam, such as the beam shown in figures 1 and 2, constructed from samples of the same sheet material used in the plastic model.

COMPARISON OF EXPERIMENTAL AND ANALOG RESULTS

By using the experience gained from the tests of the simple box beam presented in the first two figures, a plastic delta-wing model was constructed and tested. The design selected was one analyzed theoretically by MacNeal and Benscoter (ref. 2) with the use of the Cal-Tech analog computer. The idealized structure analyzed by the analog computer

was believed closely representative of the actual structure; however, no experimental verification had been obtained and it was believed possible that such information might be provided by a plastic-model test. The plan form of the delta wing and the stresses obtained are shown in figure 3.

The wing as analyzed by the analog computer has a 90-inch semispan and an 80-inch-chord line at the root. The leading edge sweeps back at 45° and the wing has a biconvex cross section. The maximum thickness is a constant 5 inches in the carry-through section and tapers from 5 inches at the root-chord line to 2 inches at the tip. The cover thickness is 0.16 inch and the interior of the wing is broken up into cells by 0.14-inch-thick spars and ribs. The wing is supported along the root-chord line indicated by the solid line. The plastic model was constructed to three-eighths the scale of these dimensions and was made of Plexiglas I-A sheet material. The stresses obtained on the plastic model were made comparable with the analog-computer stresses by means of a similarity factor determined from the scale factor of the models. The results are shown for three loading cases: a tip load at the trailing edge, a tip load at the leading edge, and a torque loading at the tip. The plastic-model stresses along the root-chord line shown by the test points agree well with the analog-computer stresses shown by the curves for each of the loading cases.

Figure 4 shows the deflections of the wing for the same three loadings. The deflections are shown for three spanwise locations as identified by the three types of test points. Again, the agreement of the results is good, which indicates that most likely both the plastic-model results and the analog-computer results are correct for this particular design.

CONCLUDING REMARKS

One distinct advantage which favors the plastic-model approach is that models may be constructed very similar to the actual design, whereas, in most theoretical structural analyses, an idealized or substitute structure is assumed in order to simplify the mathematics. In the case of the relatively simple delta design presented here, the idealized or substitute structure analyzed by the analog computer was accurately representative of the actual structure. In practice, however, many cases exist where the proper idealization of the actual structure for theoretical purposes is uncertain. In such cases, the behavior of the structure might be obtained from tests of plastic models. It is believed that a more general use of

plastic models for experimental structural analyses could contribute valuable information for some of the problems now associated with aircraft structures.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., April 22, 1955.

REFERENCES

1. Redshaw, S. C., and Palmer, P. J.: The Construction and Testing of a Xylonite Model of a Delta Aircraft. The Aeronautical Quarterly, vol. III, pt. II, Sept. 1951, pp. 83-127.

2. MacNeal, Richard H., and Benscoter, Stanley U.: Analysis of Multicell Delta Wings on Cal-Tech Analog Computer. NACA TN 3114, 1953.

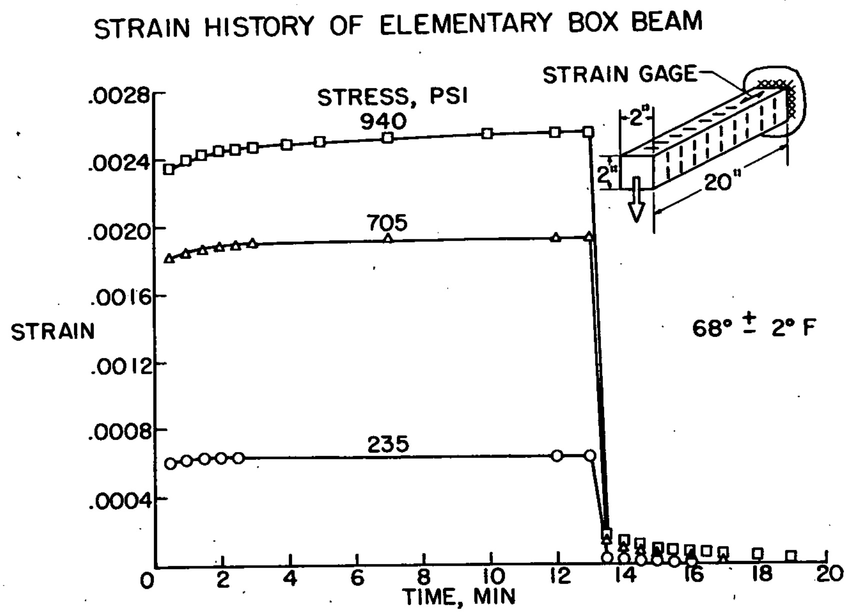

Figure 1

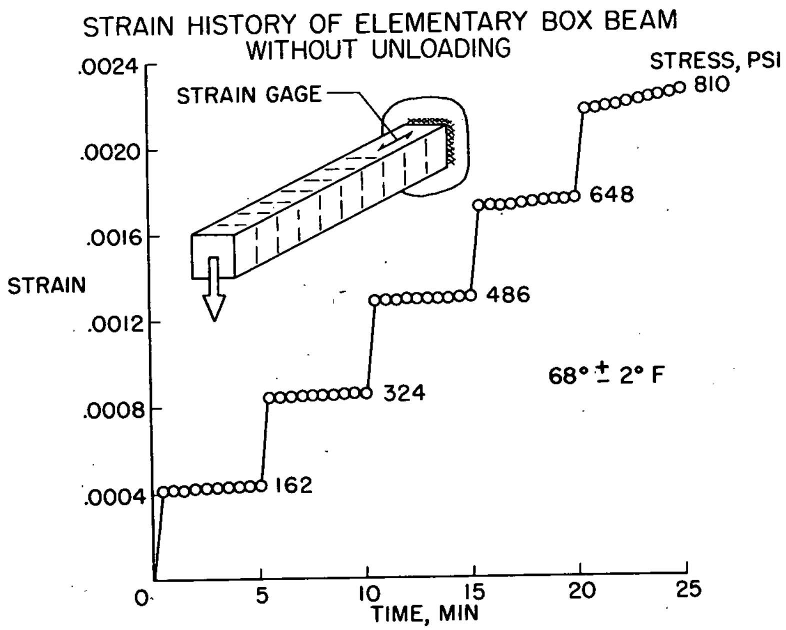

Figure 2

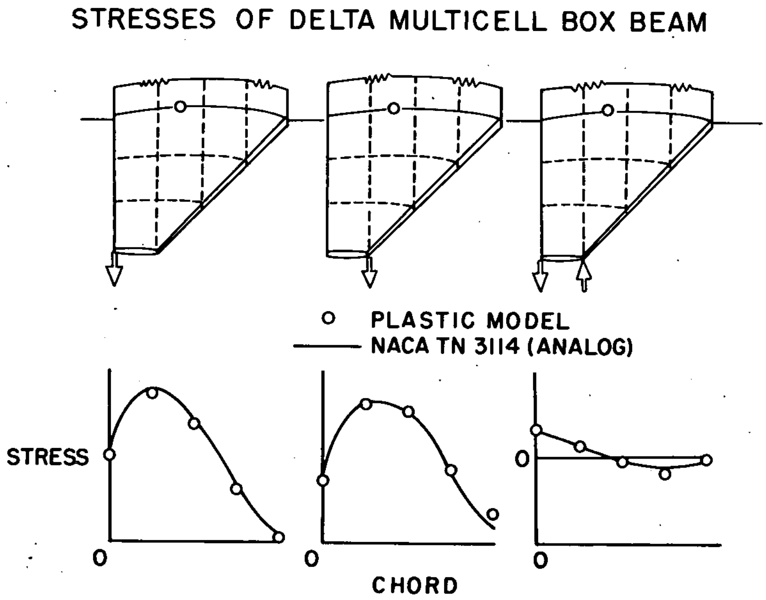

Figure 3

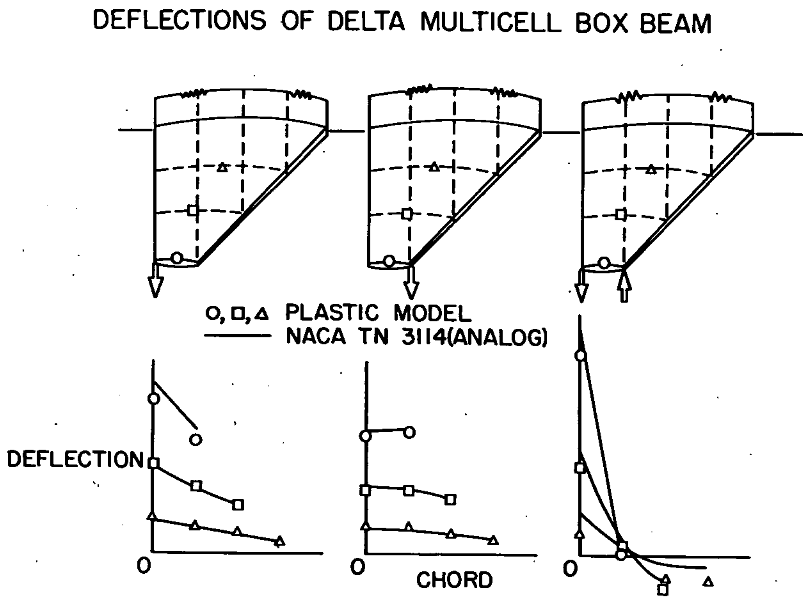

Figure 4